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Duane Arnold Energy Center

CEDAR RIVER OPERATIONAL ECOLOGICAL STUDY ANNUAL REPORT

January 1998 – December 1998

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INTRODUCTION

This report presents the results of the physical, chemical, and biological studies of the Cedar River in the vicinity of the Duane Arnold Energy Center during the 25th year of station operation (January 1998 to December 1998).

The Duane Arnold Energy Center Operational Study was implemented in mid-January, 1974. Prior to plant start-up extensive preoperational data were collected from April, 1971 to January, 1974. These preoperational studies provided a substantial amount of "baseline" data with which to compare the information collected since the station became operational. The availability of the 25 years of operational data, collected under a variety of climatic and hydrological conditions, provides an excellent basis for the assessment of the effects of the operation of the Duane Arnold Energy Center on the limnology and water quality of the Cedar River. Equally important is the availability of sufficient data to identify long-term trends in the water quality of the Cedar River which are unrelated to station operation, but are indicative of climatic patterns, changes in land use practices, or pollution control procedures within the Cedar River basin.

SITE DESCRIPTION

The Duane Arnold Energy Center, a nuclear fueled electrical generating plant, operated by Alliant Energy (formally I.E.S. Utilities Inc.), is located on the west side of the Cedar River, approximately two and one-half miles north-northeast of Palo, Iowa, in Linn County. The plant employs a boiling water nuclear power reactor which produces approximately 560 MWe of power (1658 MWth) at full capacity. Waste heat rejected from the turbine cycle to the condenser circulating water is removed by two closed loop induced draft cooling towers which required a maximum of 11,000 gpm (ca. 24.5 cfs) of water from the Cedar River. A maximum of 7,000 gpm (ca. 15.5 cfs) may be lost through evaporation, while 4,000 gpm (ca. 9 cfs) may be returned to the river as blowdown water from the cool side of the cooling towers.

OBJECTIVES

Studies to determine the baseline physical, chemical, and biological characteristics of the Cedar River near the Duane Arnold Energy Center prior to plant start-up were instituted in April of 1971. These preoperational studies are described in earlier reports.[1-3] Data from these studies served as a basis for the development of the operational study.

The operational studies were designed to identify and evaluate any significant effects of chemical or thermal discharges from the generating station into the Cedar River, as well as to assess the magnitude of impingement of the fishery on intake screens. These were first implemented in January, 1974 and have continued without interruption through the current year.[4-27]

The specific objectives of the operational study are twofold:

1. To continue routine water quality determinations in the Cedar River in order to identify any conditions which could result in environmental or water quality problems.
2. To conduct physical, chemical, and biological studies in and downstream of the discharge canal and to compare the results with similar studies executed above the intake. This will make possible the determination of any water quality changes occurring as a result of chemical additions or condenser passage, and to identify any impacts of the plant effluent on aquatic communities downstream of the discharge.

STUDY PLAN

During the operational phase of the study sampling sites were established in the discharge canal and at four locations in the Cedar River (Figure 1): 1) upstream of the plant at the Lewis Access Bridge (Station 1); 2) directly upstream of the plant intake (Station 2); 3) at a point within the mixing zone approximately 140 feet downstream of the plant discharge (Station 3); and 4) adjacent to Comp Farm, located about one-half mile below the plant (Station 4). Samples were also taken from the discharge canal (Station 5).

Prior to 1979, samples were collected and analyzed by the Department of Environmental Engineering of the University of Iowa. From January, 1979 through December, 1983 samples were collected an analyzed by Ecological Analysts, Inc. Since 1984 collection and analysis of samples has been conducted by the University of Iowa Hygienic Laboratory, located in Iowa City, Iowa. The conclusions contained in this annual report are based on the results of their analyses. Samples for routine physical, chemical, and biological analysis were taken twice per month, while other studies were conducted seasonally. The following are discussed in this report:

I. General Water Quality Analysis

- A. Frequency: twice per month
- B. Location: at all five stations
- C. Parameters Measured:
  1. Temperature
  2. Turbidity
  3. Solids (total, dissolved, and suspended)
  4. Dissolved oxygen
  5. Carbon dioxide
  6. Alkalinity (total and carbonate)
  7. pH
  8. Hardness series (total and calcium)
  9. Phosphate series (total and ortho)
  10. Ammonia
  11. Nitrate
  12. Iron
  13. Biochemical oxygen demand
  14. Coliform series (fecal and *E. coli*)

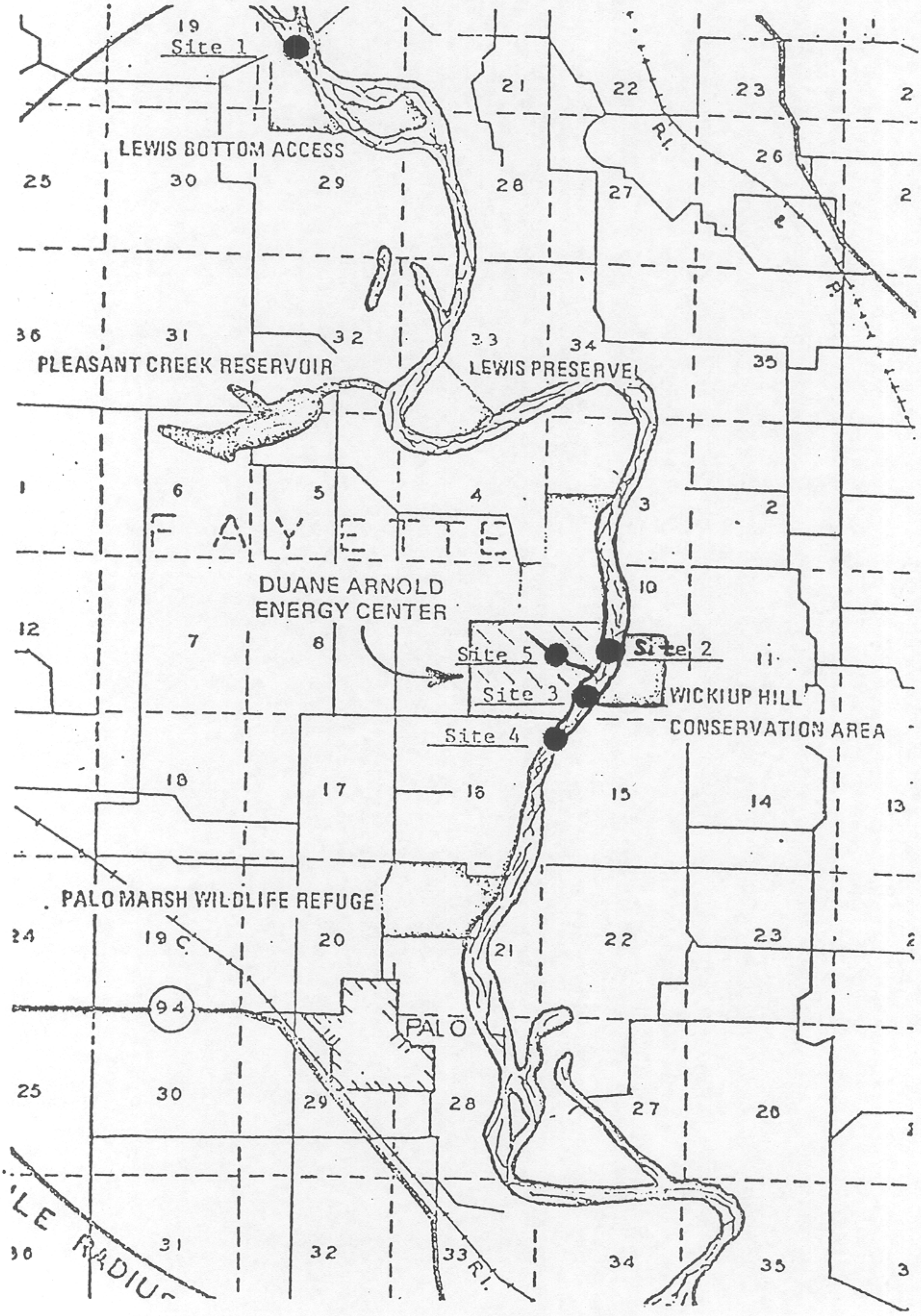

Figure 1. Location of Operational Sampling Sites

II. Additional Chemical Determinations

A. Frequency: twice yearly (April and July)

B. Locations: at all five stations

C. Parameters Measured:

1. Chromium
2. Copper
3. Lead
4. Manganese
5. Mercury
6. Zinc
7. Chloride
8. Sulfate

III. Biological Studies

A. Benthic Studies:

1. Frequency: July and August
2. Location: at all five stations

B. Impingement Studies:

1. Frequency: daily
2. Location: intake structure

C. Asiatic Clam (Corbicula) and Zebra Mussel (Dreissena) Surveys:

1. Frequency: twice yearly (May and September)
2. Location: upstream and downstream of the plant, intake bay, cooling tower basin, and discharge canal. The Zebra mussel survey also included Pleasant Creek Reservoir.

OBSERVATIONS

Physical Conditions

Hydrology (Table 1)

Mean river discharge for 1998 was higher than that present in 1997 due largely to high early summer and late fall flows. Estimated mean flow for 1998 was 6,024 cfs, substantially higher than the average flow of 5,257 cfs observed during the 27 years of the Cedar River water quality study. This is the highest mean flow observed since 1993 and the eighth highest flow observed since the study was implemented in 1972. Mean monthly discharge at the U.S. Geological Survey gauging station in Cedar Rapids ranged from 1,616 cfs in January to 13,280 cfs in June. Flows in excess of the 1903-1996 median monthly average occurred in all months except March. The lowest daily flow, 852 cfs, occurred on January 12 while a maximum daily discharge of 25,900 cfs occurred on June 26.

River flows remained relatively low from January to mid-February ranging from 852 to 2,770 cfs and then increased to 7,000 cfs by the end of the month. Flows remained relatively stable until March 31 and then increased rapidly to an April high of 19,300 cfs by April 3 and remained in excess of 9,000 cfs through late April. River discharge declined in May to ca 4,100 cfs by May 23 but increased rapidly in June and remained in excess of 10,000 cfs from June 13 through July 9. Flows ranged from ca 6,000 to 2,700 cfs from mid-July through early September falling to 1,900 cfs by the end of the month. Discharge increased in October and November reaching a fall peak of 8,410 cfs on October 20 and remained in excess of 4,000 cfs through early December. A minimum December flow of 919 cfs occurred on December 23. Hydrological data are summarized in Table 1.

<u>Temperature</u> (Table 2)

In 1998, ambient upstream river temperatures at Station 1 and 2 ranged from 0.5°C (32.9°F) from late January through early February to 26.0°C (78.8°F) on July 22. The maximum temperature observed was 2°C (3.6°F) lower than the maximum present in 1997[27] and similar to the 1980-1998 average maximum of 27.7°C (80.1°F). A maximum downstream temperature of 26°C (78.8°F) was also observed at Stations 3 and 4 on July 22. The highest discharge canal temperature observed during the 1998 study was 28.5°C (83.3°F) on August 20.

Station operation continued to have a negligible effect on downstream water temperatures. A maximum temperature differential (ΔT) between upstream temperatures at Station 2 and downstream at Station 4 of 1°C (1.8°F) was measured on October 8. The maximum temperature differential between the ambient river and the discharge canal (Station 5) observed during the

1998 study was 7.0°C (12.6°F) on both February 18 and December 16. In most cases however discharge canal temperatures were less than 4.5°C (8.1°F) higher than ambient river temperatures. Obviously there were no observed instances in which downstream river temperatures exceeded upstream river temperatures by more than the Iowa Water Quality standard of 3°C[28]. A summary of water temperature differentials between upstream and downstream locations is given in Table 3.

Turbidity (Table 4)

Average river turbidity values during 1998 were the highest observed since 1993 (Table 27). Peak values of 130 to 140 NTU occurred on October 20. High values of 130 NTU were also observed in early April. Low values of 3 NTU occurred in January during a period of low river flow.

Turbidity values in the discharge canal exhibited considerable fluctuation: high values of 200 NTU were observed in June. Low values of 7 to 10 NTU occurred in January and February.

Solids (Table 5-7)

Solids determination included total, dissolved and suspended. Total solids values in upstream river samples in 1998 were generally higher than those observed in 1997. Maximum values of 550 to 560 mg/L occurred in October during a period of high river flow. Most total solids values were between 400 and 450 mg/L.

Dissolved solids values in the upstream river were higher than those present in 1997 ranging from 240 mg/L in August to 380 mg/L in January. Dissolved solids in the discharge canal were usually much higher than in the river, ranging from 310 mg/L in May when the station was off line to 1,720 mg/L in January. As in most previous years, dissolved solids values at downstream locations were slightly higher than levels observed upstream ranging from 270 to 400 mg/L.
Low suspended solids of 1 to 4 mg/L occurred in late January and early February. High values, 240 to 260 mg/L, occurred in late October during a period of increasing runoff. Suspended solids values in the discharge canal exhibited considerable variation. Low values of 8 mg/L were present in January while high values of 240 mg/L occurred in June.

Chemical Conditions

Dissolved Oxygen (Table 8)

Dissolved oxygen concentrations in river samples collected in 1998 ranged from 6.5 to 13.8 mg/L (76 to 105% saturation). Dissolved oxygen concentrations of 12.1 to 13.8 mg/L (95 to 105% saturation) were consistently present from January through mid-March. Concentrations varied from ca 6.5 to 11.0 mg/L from April through October and then increased ranging from ca 11 to 13 mg/L for the remainder of the year. Lowest concentrations were observed in early July. Unlike 1997 supersaturated dissolved oxygen concentrations associated with algal photosynthesis were rarely observed during 1998.

Dissolved oxygen concentrations in the discharge canal (Station 5) were generally lower than river levels. Discharge canal concentrations ranged from 2.3 mg/L (30% saturation) in late August to 11.5 mg/L (84% saturation) in late January and early February. Differences in dissolved oxygen concentrations at upstream and downstream locations were minimal and station operation appeared to have no significant impact on dissolved oxygen concentrations below the plant.

Carbon Dioxide (Table 9)

Carbon dioxide concentrations were low throughout 1998. Maximum values of 4 to 7 mg/L were present in July. Minimum values of 1 mg/L or less commonly occurred throughout the year. Concentrations in the discharge canal could only rarely be determined but, based on pH values, were doubtlessly higher than river levels. A maximum discharge canal value of 13 mg/L was observed on October 8.

Alkalinity, pH, Hardness (Tables 10-14)

These interrelated parameters are influenced by a variety of factors including hydrological, climatic and biological conditions.

Total alkalinity values in the 1998 river samples were generally higher than those observed in 1997. Values ranging from 132 mg/L in early April at the beginning of a period of snowmelt and runoff to 238 mg/L in November. Total alkalinity values in the discharge canal ranged from 82 to 294 mg/L.

Carbonate alkalinity was rarely present in river samples during 1998. The highest carbonate value 16 mg/L, occurred in September. Carbonate alkalinity was only observed on two occasions in the discharge canal.

Values for pH in river samples exhibited minimal variation in 1998 ranging from 7.6 to 8.7. Values of less than 8 units were only rarely present in river samples. Due to the addition of buffering agents, pH values in the discharge canal were generally lower.

Average total hardness values in the 1998 upstream river samples were the highest observed during the 27 years of the study (Table 27) and generally exhibited a pattern similar to that observed for total alkalinity. Lowest values 200 mg/L occurred in early April while highest levels, 380 to 400 mg/L were present in late January. Calcium hardness values were also high and paralleled total hardness values. Low values of 130 mg/L occurred in April and May. High values of 230 to 240 mg/L occurred in January and December.

Hardness values in the discharge canal continued to be consistently higher than levels present in the river; a result of reconcentrations in the blow down from the towers. Total hardness values in the discharge canal ranged from 270 to 1,100 mg/L. As a result of high hardness values in the discharge canal, downstream levels were usually slightly higher than those present upstream (Table 26).

Phosphates (Table 15 and 16)

Phosphate concentrations in the 1998 samples were similar to or slightly lower than those present in 1997 (Table 27). Total phosphate concentrations ranged from 0.1 mg/L in December to 0.6 mg/L in mid-February. Levels in the discharge canal were consistently higher than river levels ranging from 0.2 to 2.3 mg/L resulting in slightly higher downstream concentrations.

Orthophosphate concentrations in the river samples ranged from 0.3 mg/L in mid-February to <0.1 mg/L in most May to August samples. Orthophosphate concentrations in the discharge canal ranged from <0.1 to 1.0 mg/L.

Ammonia (Table 17)

Ammonia concentrations in the 1998 river samples remained low throughout the year. Maximum concentrations, 0.3 mg/L (as N) occurred in mid-February. Values of less than 0.1 mg/L (as N) were consistently present from April through December. Ammonia concentrations in the discharge were generally slightly higher, ranging from <0.1 to 1.4 mg/L (as N).

Nitrate (Table 18)

Average nitrate concentrations in river samples were the highest present since 1991 (Table 27). Low values of 3.1 to 4.0 mg/L (as N) were present in August and September. Maximum nitrate concentrations of 12 to 13 mg/L (as N) were present in June.

Nitrate concentrations in the discharge canal were almost always higher than river levels. A maximum nitrate concentration of 41 mg/L (as N) was observed in the discharge canal on June 3 but downstream effects were minimal.

Iron (Table 19)

Iron concentrations in the 1998 river samples continued to be high. Concentrations ranged from 0.06 mg/L in January to 8.4 mg/L in October. As in previous years, high iron concentrations frequently accompanied increased turbidity and suspended solids levels indicating that most of the iron was in suspended form rather than in solution. Iron levels in the discharge canal were usually slightly higher than river levels ranging from 0.35 to 12 mg/L.

Biological Studies

Biochemical Oxygen Demand (Table 20)

Five day biochemical oxygen demand (BOD_5) values in the 1998 river samples were the lowest observed since 1993 (Table 27). Maximum BOD levels (6 to 8 mg/L) occurred at intervals from May to September. High values, associated with runoff, were not observed in 1998. Low values of <1 mg/L were present in January, November and December. BOD levels in the discharge canal were generally similar to those present at river locations.

Coliform Organisms (Tables 21 and 22)

Coliform determinations included enumeration of fecal coliforms as well as specific determination of Escherichia coli.

Maximum river concentrations of fecal coliform and E. coli of 5,100 and 4,000 organisms/100 ml respectively were observed downstream of the discharge canal (Station 3) on August 6. High coliform levels were also present at the upstream locations on this date. Both fecal coliform and E. coli concentrations exhibited wide fluctuations during the year but in general lowest values, 20 to 50 organisms/100 ml, were present during the winter months.

Extremely high fecal coliform and E. coli concentrations of 61,000 and 77,000 organisms/100 ml respectively were observed in the discharge canal on April 1. It appeared that these high levels resulted from localized land runoff flowing into the discharge canal, following a period of rainfall and heavy runoff and were unrelated to station operation. A similar situation occurred in 1997. Although high coliform concentrations were present sporadically in the discharge canal the effect on the downstream river was minimal.

ADDITIONAL STUDIES

In addition to the routine twice monthly studies, a number of seasonal limnological and water quality investigation were conducted in 1998. The studies discussed here include additional chemical determinations, benthic surveys, Asiatic clam (Corbicula) and zebra mussel (Dreissena) surveys and impingement surveys.

Additional Chemical Determinations

Samples for additional chemical determinations were collected on April 15 and July 1, 1998 from all river locations and in the discharge canal and analyzed for chloride, sulfate, chromium, copper, lead, maganese, mercury and zinc. Concentrations of all parameters fell within the expected ranges.

Chloride and sulfate concentrations were similar at all river locations on both sampling dates and also similar to values observed in 1996 and 1997[26,27]. In 1998, chloride concentrations in river samples ranged from 10 to 22 mg/L. Sulfate concentrations ranged from 17 to 26 mg/L.

Levels of the heavy metals chromium, copper, lead and mercury were below detection limits in all river samples. Manganese values in the river ranged from 130 to 150 ug/L in April to 50 to 100 ug/L in July. Levels of zinc exhibited considerable fluctuation ranging from less than 20 ug/L at downstream river locations to 220 ug/L upstream (Station 2) on April 15.

Reconcentration of solids in the blowdown from the cooling towers resulted in increased levels of chlorides, sulfates, manganese and zinc in the July 1998 samples from the discharge canal but except for zinc downstream increases were negligible. The station was operating at reduced power on April 15 and levels of the above mentioned parameters in the discharge canal were similar to those present at other locations. Sulfate concentrations present in the discharge canal on both sampling dates were substantially lower than those present in 1997[27]. Sulfate concentrations exhibited no increases at downstream locations on April 15 and only minimal increases on July 1. These decreases in sulfate levels are probably the result of changes in the treatment procedures for the cooling water which have resulted in the addition of less sulfuric acid for pH control. The results of additional chemical determinations are presented in Table 23.

Benthic Studies

Artificial substrate samplers (Hester-Dendy) were placed at each of the four sampling locations, upstream and downstream of the discharge canal and in the discharge canal on July 20 and August 28, 1998. These substrates were collected on August 26 and October 10, 1998 following a six week period to allow for the development of a benthic community.

As in past studies, the benthic communities which developed on the substrates were much larger and more diverse than those found in the shifting sand and silt bottom characteristic of the Cedar River in the vicinity of the Duane Arnold Energy Center. Ponar grab samples taken from the five sites contain few if any benthic organisms, but a diverse assemblage of organisms develop on the substrates during the six week colonization period.

In 1998 a total of 36 taxa were identified during the two sampling periods, 26 in August and 27 in October. These included 30 species (6 orders) of insects, two annelids, one snail, one nematode and one flatworm. Chironomid larvae (Diptera) were the dominant organisms in the August samples while caddis flies were dominant in October.

Both the total numbers and diversity of organisms in the discharge canal continued to be far lower than in the river. Only 8 taxa; two in August and six in October were present. A total of 769 organisms, 2 in August and 767 in October were present on the discharge canal substrates. The October discharge canal samples consisted primarily of snails.

In general, there was little difference in the composition of benthic populations between upstream and downstream locations in the August studies although total numbers were higher at the Lewis Access location (Station 1). In October the composition and size of the benthic population at the river locations were similar but total number of organisms were lower than in the August samples. The substrates from the Lewis Access site (Station 1) could not be recovered in the October study.

As in prior years the artificial substrate studies indicate that the Cedar River, both upstream and downstream of the Duane Arnold Energy Center is capable of supporting a relatively diverse benthic macroinvertebrate fauna in those limited areas where a suitable substrate is available. The discharge canal however, is not a suitable habitat for most benthic organisms. The results of the benthic studies are presented in Table 24.

Asiatic Clam and Zebra Mussel Surveys

In past years a number of power generation facilities experienced problems with blockage of cooling water intake systems by large numbers of Asiatic clams (Corbicula sp.). Although this clam commonly occurs in portions of the Iowa reach of the Mississippi River, it is normally absent from areas with shifting sand/silt substrates such as occur in the Cedar River in the vicinity of the Duane Arnold Energy center. Corbicula has not been collected from the Cedar River in the vicinity of the DAEC during the routine monitoring program, which was implemented in April of 1971. A single Corbicula was, however, collected in January of 1979 in the vicinity of Lewis Access, upstream of DAEC, by Hazelton personnel. Because Corbicula has been reported on one occasion from the Cedar River and is commonly found in power plant intakes on the Mississippi River, studies were implemented at the Duane Arnold Energy Center in 1981 to determine if the organism was present in the vicinity of the station or had established itself within the system. No Corbicula were collected during the 1981 to 1997 investigations[11-27]. The zebra mussel (Dreissena polymorpha) is a European form which was first found in the United States in Lakes St. Clair and Erie in 1988. The zebra mussel has been a major problem at many power plant intakes as well as a number of municipal water treatment plants in the United States. The organisms tend to grow in clumps attached to a solid substrate and can rapidly clog intake structures, screens, and pipes. It is difficult to control chemically and frequently must be removed mechanically. The mussel is adapted to both river and lake habitats and does especially well in enriched waters which support large plankton populations that it utilizes as food. Unlike the Asiatic clam (Corbicula), it is capable of living in cold waters and does not require a silty substrate.

Since its introduction into the United States the zebra mussel has rapidly expanded its range. It is now found in all of the Great Lakes. In 1991, just three years after they were first found in the U.S., they were collected in the Hudson, Illinois, Mississippi, Ohio, Susquehanna, Tennessee, and Cumberland Rivers[29]. The U.S. Army Corps of Engineers reports that zebra mussel populations have increases exponentially on lock and dam surfaces since their introduction into the Mississippi River in 1991[30,31] and the organism has also established itself at several locations in the Iowa reach of the Mississippi River. Zebra mussel populations increased rapidly in the Iowa reach of the Mississippi River in 1994 and 1995 but populations appear to have remained relatively constant since 1996 and the zebra mussel has not been observed in the Iowa tributaries of the Mississippi River.

Studies were conducted twice monthly from May through November 1998 in the Pleasant Creek Reservoir and Cedar River in the vicinity of the Duane Arnold Energy Center by Dr. J.K. Johnson. Dr. Johnson did not observe any veliger (larval) or adult zebra mussels in the course of his investigations[32].

Additional studies were also conducted by the University of Iowa Hygienic Laboratory in May and September 1998 to determine if either Asiatic clams or zebra mussels were present in the vicinity of the Duane Arnold Energy Center. Sampling was carried out upstream and downstream of the station, in the intake bay, the cooling tower basin and discharge canal as well as in the Pleasant Creek Reservoir utilizing a mussel rake and Ponar sampler, as well as visual inspections of appropriate substrates. No Asiatic Clams or zebra mussels were found at any of the sites of during the 1998 investigations.

Impingement Studies

The total number of fish impinged on the intake screens at the Duane Arnold Energy Center during ~~1997~~ 1998 as reported by Alliant personnel, remains very low. Daily counts indicated a total of only 394 fish were impinged during 1998. Highest impingement occurred during the late fall to early spring period. During the months of February, March and December 283 fish, or approximately 72% of the yearly impingement total, were removed from the trash baskets. Lowest impingement rates occurred from August through October when only 11 fish were removed from the trash baskets. The month with the highest impingement rate was February when 104 fish were collected in the trash baskets. The results of the daily trash basket counts are given in Table 25.

DISCUSSION AND CONCLUSIONS

The Duane Arnold Energy Center has been operational for twenty four years. During that time the impact of station operation on the limnology and water quality of the Cedar River has been minimal. In 1998, as in past years, the major factors influencing the water quality of the Cedar River have been climatic and hydrological conditions and agricultural activities within the Cedar River basin.

During 1998 the mean discharge in the Cedar River was 6,024 cfs. This flow was substantially higher than the 1997 mean flow of 4,996 cfs and the eighth highest flow present since the Cedar River water quality was implemented in 1972. Flows in excess of the 1903-1996 median monthly average occurred in all months except March. Maximum flows occurred in June. Average discharge from the cooling towers into the Cedar River is only about 9 cfs and as expected the station had a negligible impact on downstream water temperatures. A maximum observed temperature differential (ΔT) between upstream temperatures at Station 2 and Station 4 located one half mile downstream of the plant was only 1.0°C (1.8°F). No other observed temperature differentials ever exceeded 0.5°C (0.9°F). When average river temperatures for the 1998 study are compared, the average temperature differential between Station 2 and Station 4 was only 0.3°C (0.5°F).

Station operation also had minimal impact on other water quality parameters. Several parameters exhibited slight increases in concentration downstream of the station but these increases were not sufficient to adversely impact aquatic life or violate applicable water quality standards. Parameters exhibiting downstream increases were dissolved solids which increased from an average of 323 mg/L at Station 2 to 335 mg/L at Station 4, total hardness which increased from 292 to 310 mg/L, total phosphate which increased from 0.28 to 0.30 mg/L, iron which increased from 2.22 to 2.39 mg/L and nitrate which increased from 7.1 to 7.2 mg/L (as N) (Table 26). These findings are similar to those observed in past years.

Additional chemical determinations conducted in April and July 1998 exhibited low concentrations of heavy metal in both the upstream and downstream river samples none of which exceeded the Iowa Water Quality standards[28]. With the exception of zinc, heavy metal concentrations in the mixing zone (Station 3) downstream of the station were similar to those observed at upstream locations. Reconcentration in the blowdown from the cooling towers resulted in increased concentrations of maganese, zinc and sulfates in the discharge canal on July 1 concentrations were not elevated at Station 4, one-half mile downstream of the station. The extremely high sulfate levels present in the discharge canal in past years were not observed during the 1998 studies (Table 23).

In general the water quality of the Cedar River during the 1998 was compatible with climatic and hydrological conditions present and it appears that agricultural activities remain the major factor influencing the limnology and water quality of the river. High average nitrate concentrations in excess of 4 mg/L (as N) have been observed in the Cedar River in most years since 1978 (Table 27). Peak average levels of 8.6 mg/L (as N) were observed in 1994 a year characterized by high river discharge. The lowest mean concentration of 1.5 mg/L (as N) occurred in 1989 when extremely low river flows were present. Nitrate concentrations declined somewhat following the record flows present in 1993 which flushed much of the nitrate from the Cedar River basin but levels have gradually increased since that time and the average nitrate concentration of 7.4 mg/L (as N) observed during the current year was the highest present since 1991. Relative loading values for nitrate obtained by multiplying average nitrate concentrations by cumulative runoff were the highest observed since 1993 (Table 28).

In past years high BOD values associated with snow melt and runoff from the river basin were frequently observed during the late winter and early spring period, but this condition was not observed during 1998. Similarly high BOD values resulting from the death and decay of large algal populations were not observed during the current year. The average BOD value of 2.8 mg/L present in 1998 was the lowest observed since 1993 when record flows were present (Table 27).

The numbers of fish impinged on the intake screens at the Duane Arnold Energy Center during 1998 was extremely low. Only 394 impinged fish were reported in 1998 as compared to 897 in 1996 and 533 in 1997. As in past years highest impingement rates occurred during the winter months. The impact of impingement on the fishery of the Cedar River continues to be insignificant.

Populations of benthic (bottom dwelling) organisms which colonized artificial substrates placed in the Cedar River in the summer and fall of 1998 were generally similar to those present in past years. Diversity was similar at upstream and downstream river locations and indicated that where adequate substrate is available the Cedar River is capable of supporting a diverse benthic biota. The paucity of organism normally present in the Cedar River in the vicinity of the Duane Arnold Energy Center is due to the shifting sand bottom which does not provide a suitable substrate for bottom dwelling organisms.

The size and diversity of benthic populations developing on substrates placed in the discharge canal continue to be far smaller than those developing on the river substrates. Obviously the discharge canal does not provide a suitable habitat for most benthic organisms.

Since 1981 studies have been conducted to determine if the Asiatic Clam is present in the vicinity of the Duane Arnold Energy Center. Studies to determine if the zebra mussel is present have been conducted since 1991. Neither Asiatic clams nor zebra mussels have been observed during these investigations. Although zebra mussels are present in the Iowa reach of the Mississippi River, populations appear to have remained relatively stable since 1996 and the mussels have not been reported from any Iowa tributes to the Mississippi

Table 1

Summary of Hydrological Conditions
Cedar River at Cedar Rapids*
1998

Date	Mean Monthly Discharge cfs	Percent of Mean Monthly Average†
January	1,616	129
February	3,488	213
March	5,887	97
April	12,030	179
May	5,788	120
June	13,280	244
July	9,677	161
August	3,870	159
September	2,506	114
October	5,040	204
November	5,769	233
December	3,344	177

*Data obtained from U.S. Geological Survey records
†Based on water years 1903-1996

Table 2

Temperature (°C) Values for the Cedar River
near the Duane Arnold Energy Center during 1998

Date 1998	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 Feet Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
	Sampling Locations				
Jan-07	2.0	2.0	4.5	2.0	2.5
Jan-22	0.5	0.5	3.5	0.5	0.5
Feb-04	0.5	0.5	4.0	0.5	0.5
Feb-18	4.5	4.0	11.0	4.5	4.5
Mar-04	3.5	3.5	8.0	3.5	4.0
Mar-19	2.5	2.5	6.5	3.0	3.0
Apr-01	10.0	10.0	9.0	10.0	10.5
Apr-15	12.5	12.5	14.0	12.5	12.5
May-04	15.0	15.0	16.5	15.0	15.5
May-20	22.0	22.0	22.0	22.0	22.0
Jun-03	18.0	18.0	21.0	18.0	18.5
Jun-16	19.0	19.5	26.0	19.5	19.5
Jul-01	23.0	23.5	27.5	23.5	24.0
Jul-22	26.0	26.0	27.5	26.0	26.0
Aug-06	22.0	22.0	26.0	22.0	22.0
Aug-20	24.5	25.0	28.5	25.0	25.0
Sep-02	21.5	22.5	24.0	22.5	22.5
Sep-16	21.5	22.0	26.5	22.0	22.5
Oct-08	12.0	12.5	14.5	13.0	13.5
Oct-20	12.0	12.0	13.0	12.5	12.5
Nov-04	7.0	7.0	11.5	7.5	7.5
Nov-18	5.5	5.5	9.5	6.0	6.0
Dec-02	9.0	9.0	11.5	9.0	9.5
Dec-16	3.0	3.5	11.5	3.5	4.0

Table 3

Summary of Water Temperature Differentials and Station Output During Periods of Cedar River Sampling in 1998

Date 1998	T (°C) Upstream River (Station 2) vs. Discharge (Station 5)	T (°C) Upstream River (Station 2) vs. Downstream River (Station 3)	T (°C) Upstream River (Station 2) vs. Downstream River (Station 4)	Station Output (% Full Power)
Jan-07	2.5	0.0	0.5	100
Jan-22	3.0	0.0	0.0	100
Feb-04	3.5	0.0	0.0	99
Feb-18	7.0	0.5	0.5	100
Mar-04	4.5	0.0	0.5	100
Mar-19	4.0	0.5	0.5	99
Apr-01	-1.0	0.0	0.5	94
Apr-15	1.5	0.0	0.0	0
May-04	1.5	0.0	0.5	0
May-20	0.0	0.0	0.0	9
Jun-03	4.0	0.0	0.5	100
Jun-16	6.5	0.0	0.0	100
Jul-01	4.0	0.0	0.5	100
Jul-22	1.5	0.0	0.0	100
Aug-06	4.0	0.0	0.0	100
Aug-20	3.5	0.0	0.0	100
Sep-02	1.5	0.0	0.0	100
Sep-16	4.5	0.0	0.5	100
Oct-08	2.0	0.0	1.0	100
Oct-20	1.0	0.5	0.5	100
Nov-04	4.5	0.5	0.5	100
Nov-18	4.0	0.5	0.5	100
Dec-02	2.5	0.0	0.5	100
Dec-16	7.0	0.0	0.5	8

Table 4

Turbidity (NTU) Values for the Cedar River near the Duane Arnold Energy Center during 1998

Date 1998	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	Sampling Locations				
	1	2	5	3	4
Jan-07	9	10	12	7	7
Jan-22	3	3	7	4	4
Feb-04	6	5	10	5	6
Feb-18	62	46	19	46	41
Mar-04	18	18	19	20	20
Mar-19	27	24	13	25	28
Apr-01	130	110	27	120	110
Apr-15	52	46	40	46	47
May-04	32	30	25	30	29
May-20	37	38	35	39	35
Jun-03	54	56	200	58	58
Jun-16	80	75	200	79	69
Jul-01	53	54	130	52	52
Jul-22	42	42	56	40	40
Aug-06	62	56	44	58	56
Aug-20	27	28	18	29	29
Sep-02	44	44	64	48	40
Sep-16	18	20	29	40	35
Oct-08	30	30	16	31	24
Oct-20	140	130	34	120	120
Nov-04	20	24	46	27	24
Nov-18	18	19	17	19	19
Dec-02	17	17	19	17	17
Dec-16	5	5	23	7	5

Table 5

Total Solids (mg/L) Values for the Cedar River
near the Duane Arnold Energy Center during 1998

Date 1998	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	Sampling Locations				
	1	2	5	3	4
Jan-07	400	400	1790	440	430
Jan-22	390	400	1600	420	410
Feb-04	370	370	1700	390	390
Feb-18	450	430	610	450	440
Mar-04	380	390	1250	390	410
Mar-19	430	430	1350	450	450
Apr-01	480	440	480	450	450
Apr-15	460	450	420	450	450
May-04	430	450	410	450	450
May-20	400	410	430	410	410
Jun-03	480	490	1950	550	520
Jun-16	450	430	1590	450	450
Jul-01	330	340	940	350	340
Jul-22	390	390	1790	440	440
Aug-06	410	420	1250	440	440
Aug-20	370	350	1710	430	430
Sep-02	410	420	1800	480	440
Sep-16	350	350	1750	450	430
Oct-08	420	430	1420	460	450
Oct-20	560	550	1440	570	550
Nov-04	430	440	1620	460	440
Nov-18	430	420	1300	450	440
Dec-02	390	370	1180	410	410
Dec-16	390	390	480	390	390

Table 6

Dissolved Solids (mg/L) Values for the Cedar River near the Duane Arnold Energy Center during 1998

Date 1998	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	Sampling Locations				
	1	2	5	3	4
Jan-07	370	370	1720	400	400
Jan-22	380	380	1540	400	370
Feb-04	350	350	1610	370	360
Feb-18	300	310	540	330	320
Mar-04	330	340	1200	350	350
Mar-19	360	350	1180	370	370
Apr-01	280	270	420	270	270
Apr-15	320	320	320	320	320
May-04	340	340	330	340	330
May-20	270	270	310	270	270
Jun-03	330	330	1580	360	360
Jun-16	320	300	1350	310	310
Jul-01	250	250	710	260	250
Jul-22	290	280	1540	290	290
Aug-06	240	260	1180	280	280
Aug-20	270	310	1690	340	330
Sep-02	300	310	1700	350	320
Sep-16	290	290	1580	320	320
Oct-08	330	320	670	350	350
Oct-20	300	310	1350	310	310
Nov-04	370	370	1460	390	390
Nov-18	370	370	1250	380	380
Dec-02	350	350	1120	370	370
Dec-16	360	350	390	370	360

Table 7

Suspended Solids (mg/L) Values for the Cedar River near the Duane Arnold Energy Center during 1998

	Sampling Locations				
Date 1998	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-07	15	14	11	16	14
Jan-22	1	2	8	1	2
Feb-04	5	4	10	6	6
Feb-18	140	110	24	110	96
Mar-04	34	30	14	32	36
Mar-19	57	53	13	55	55
Apr-01	170	130	22	140	140
Apr-15	100	90	75	90	94
May-04	64	66	46	64	63
May-20	100	99	78	96	110
Jun-03	110	120	240	120	120
Jun-16	120	100	240	110	110
Jul-01	56	48	160	51	54
Jul-22	100	120	90	120	110
Aug-06	150	140	63	140	130
Aug-20	58	63	25	65	59
Sep-02	94	89	110	97	100
Sep-16	46	48	42	100	86
Oct-08	64	67	13	72	59
Oct-20	260	240	39	250	240
Nov-04	36	39	120	39	38
Nov-18	30	30	18	33	33
Dec-02	27	26	23	28	26
Dec-16	10	10	71	12	11

Table 8

Dissolved Oxygen (mg/L) Values for the Cedar River near the Duane Arnold Energy Center during 1998

	Sampling Locations				
Date 1998	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-07	12.5	12.8	9.7	12.6	12.7
Jan-22	13.0	13.6	11.5	13.3	13.5
Feb-04	13.5	13.6	11.5	13.4	13.5
Feb-18	12.1	12.2	9.8	12.4	12.5
Mar-04	13.4	13.4	10.6	13.2	13.8
Mar-19	13.4	13.2	11.2	13.3	12.9
Apr-01	10.1	9.5	8.6	9.6	9.8
Apr-15	9.8	10.0	9.6	9.9	10.0
May-04	10.6	10.7	11.4	11.2	10.6
May-20	9.5	9.9	8.8	9.8	9.7
Jun-03	9.2	9.1	8.4	9.0	9.3
Jun-16	8.2	8.4	7.8	8.4	8.3
Jul-01	7.4	6.8	7.8	6.5	6.7
Jul-22	8.3	8.0	6.0	7.8	8.0
Aug-06	8.6	8.6	3.9	8.5	8.5
Aug-20	8.5	8.9	2.3	8.9	9.8
Sep-02	8.7	9.4	6.2	9.2	9.5
Sep-16	9.6	10.9	3.1	10.7	11.7
Oct-08	9.7	10.0	3.3	10.2	10.0
Oct-20	9.6	9.8	6.3	9.6	9.6
Nov-04	11.6	11.4	7.7	11.3	11.7
Nov-18	12.2	12.0	6.5	11.5	11.8
Dec-02	11.0	11.2	7.0	10.9	11.0
Dec-16	12.9	13.0	10.4	12.8	12.7

Table 9

Carbon Dioxide (mg/L) Values for the Cedar River near the Duane Arnold Energy Center during 1998

Date 1998	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	Sampling Locations				
	1	2	5	3	4
Jan-07	<1	<1	*	<1	<1
Jan-22	<1	3	*	<1	<1
Feb-04	<1	<1	*	<1	4
Feb-18	2	2	3	3	4
Mar-04	<1	<1	*	<1	<1
Mar-19	<1	2	*	<1	<1
Apr-01	3	4	5	3	4
Apr-15	2	3	3	3	3
May-04	<1	<1	2	<1	<1
May-20	1	1	<1	<1	<1
Jun-03	<1	<1	*	<1	<1
Jun-16	3	2	*	3	3
Jul-01	4	5	<1	5	7
Jul-22	1	1	*	2	2
Aug-06	2	2	*	2	2
Aug-20	1	<1	*	<1	<1
Sep-02	<1	<1	*	<1	<1
Sep-16	<1	<1	*	<1	<1
Oct-08	<1	<1	13	<1	<1
Oct-20	2	2	*	2	2
Nov-04	<1	<1	*	<1	<1
Nov-18	<1	<1	*	<1	<1
Dec-02	<1	<1	*	<1	<1
Dec-16	<1	<1	3	<1	<1

*Unable to calculate

Table 10

Total Alkalinity (mg/L) Values for the Cedar River near the Duane Arnold Energy Center during 1998

	Sampling Locations				
Date 1998	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-07	200	198	108	194	98
Jan-22	234	236	116	228	230
Feb-04	200	194	106	204	196
Feb-18	170	178	184	182	180
Mar-04	194	192	114	192	194
Mar-19	194	186	100	184	180
Apr-01	132	146	106	138	140
Apr-15	174	192	194	192	186
May-04	210	198	180	186	212
May-20	148	142	194	144	150
Jun-03	194	198	134	186	176
Jun-16	162	152	142	162	164
Jul-01	146	152	294	160	156
Jul-22	166	148	84	168	156
Aug-06	158	160	94	164	156
Aug-20	158	160	120	152	160
Sep-02	184	196	82	204	202
Sep-16	182	188	116	180	184
Oct-08	212	202	200	192	200
Oct-20	172	172	218	174	174
Nov-04	226	238	142	228	228
Nov-18	236	230	176	226	240
Dec-02	232	230	194	230	228
Dec-16	230	228	198	232	232

Table 11

Carbonate Alkalinity (mg/L $CaCO_3$) Values for the Cedar River near the Duane Arnold Energy Center during 1998

Date 1998	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	Sampling Locations				
	1	2	5	3	4
Jan-07	2	2	<1	2	2
Jan-22	2	<1	<1	2	2
Feb-04	2	2	<1	2	<1
Feb-18	<1	<1	<1	<1	<1
Mar-04	2	2	<1	2	2
Mar-19	2	<1	<1	<1	2
Apr-01	<1	<1	<1	<1	<1
Apr-15	<1	<1	<1	<1	<1
May-04	6	6	<1	6	6
May-20	<1	<1	6	2	2
Jun-03	2	2	<1	2	2
Jun-16	<1	<1	<1	<1	<1
Jul-01	<1	<1	28	<1	<1
Jul-22	<1	<1	<1	<1	<1
Aug-06	<1	<1	<1	<1	<1
Aug-20	<1	2	<1	2	2
Sep-02	4	2	<1	8	10
Sep-16	4	16	<1	16	10
Oct-08	2	2	<1	2	2
Oct-20	<1	<1	<1	<1	<1
Nov-04	4	4	<1	4	4
Nov-18	4	4	<1	4	4
Dec-02	6	4	<1	6	4
Dec-16	4	2	<1	4	4

Table12

Units of pH Values for the Cedar River
near the Duane Arnold Energy Center during 1998

Date 1998	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-07	8.7	8.7	8.3	8.7	8.7
Jan-22	8.4	8.3	8.3	8.4	8.4
Feb-04	8.4	8.4	8.2	8.4	8.2
Feb-18	8.3	8.3	8.2	8.3	8.1
Mar-04	8.4	8.6	8.2	8.6	8.4
Mar-19	8.4	8.3	7.6	8.2	8.4
Apr-01	8.0	7.9	7.7	8.0	7.9
Apr-15	8.2	8.2	8.1	8.2	8.1
May-04	8.5	8.5	8.3	8.5	8.6
May-20	8.3	8.3	8.6	8.4	8.4
Jun-03	8.5	8.4	8.0	8.5	8.4
Jun-16	8.1	8.1	7.9	8.1	8.1
Jul-01	7.8	7.8	8.6	7.8	7.6
Jul-22	8.3	8.3	7.6	8.2	8.3
Aug-06	8.3	8.3	7.4	8.3	8.3
Aug-20	8.3	8.4	7.5	8.4	8.5
Sep-02	8.5	8.6	7.6	8.5	8.6
Sep-16	8.6	8.7	7.5	8.7	8.7
Oct-08	8.4	8.4	7.5	8.5	8.4
Oct-20	8.2	8.3	7.6	8.3	8.2
Nov-04	8.5	8.6	7.7	8.6	8.6
Nov-18	8.5	8.5	7.6	8.6	8.5
Dec-02	8.5	8.5	7.7	8.5	8.5
Dec-16	8.6	8.3	8.2	8.4	8.6

Sampling Locations spans columns 2–6.

Table 13

Total Hardness (mg/L $CaCO_3$) Values for the Cedar River near the Duane Arnold Energy Center during 1998

Date 1998	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	Sampling Locations				
	1	2	5	3	4
Jan-07	280	280	1100	300	290
Jan-22	380	400	1000	360	380
Feb-04	290	280	1000	290	330
Feb-18	280	320	440	280	310
Mar-04	280	280	790	300	310
Mar-19	350	350	960	340	360
Apr-01	200	200	290	200	200
Apr-15	280	270	270	280	280
May-04	300	300	330	310	300
May-20	280	270	300	240	230
Jun-03	340	340	1100	370	340
Jun-16	260	260	840	250	270
Jul-01	310	250	600	230	310
Jul-22	240	240	1000	240	240
Aug-06	240	300	790	260	260
Aug-20	240	250	1100	260	210
Sep-02	250	270	1100	280	270
Sep-16	290	280	1100	300	290
Oct-08	260	260	880	270	280
Oct-20	220	220	870	240	220
Nov-04	300	290	950	300	300
Nov-18	370	320	980	370	380
Dec-02	340	340	760	360	360
Dec-16	300	310	340	320	200

Table 14

Calcium Hardness (mg/L $CaCO_3$) Values for the Cedar River near the Duane Arnold Energy Center during 1998

Date 1998	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-07	210	180	720	220	220
Jan-22	230	230	700	240	230
Feb-04	190	180	670	190	200
Feb-18	180	190	330	190	210
Mar-04	200	220	580	210	220
Mar-19	210	230	730	260	210
Apr-01	150	130	210	140	130
Apr-15	190	190	190	190	190
May-04	210	220	220	220	200
May-20	130	130	160	130	150
Jun-03	220	220	760	220	210
Jun-16	180	170	600	170	180
Jul-01	150	150	410	150	150
Jul-22	150	140	600	150	140
Aug-06	140	140	440	160	160
Aug-20	160	160	730	200	150
Sep-02	170	200	720	200	180
Sep-16	140	170	640	200	150
Oct-08	180	170	590	180	180
Oct-20	150	150	590	150	150
Nov-04	200	210	650	220	220
Nov-18	220	220	640	220	240
Dec-02	220	240	570	240	220
Dec-16	180	190	200	190	190

Table 15

Total Phosphorus (mg/L-P) Values for the Cedar River near the Duane Arnold Energy Center during 1998

Date 1998	Sampling Locations: Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-07	0.2	0.2	1.7	0.2	0.2
Jan-22	0.2	0.2	1.5	0.2	0.2
Feb-04	0.2	0.3	1.9	0.3	0.3
Feb-18	0.6	0.5	0.8	0.6	0.5
Mar-04	0.2	0.2	1.5	0.2	0.2
Mar-19	0.3	0.4	1.0	0.3	0.3
Apr-01	0.5	0.5	0.5	0.5	0.5
Apr-15	0.2	0.2	0.3	0.2	0.2
May-04	0.2	0.2	0.2	0.2	0.2
May-20	0.2	0.2	0.7	0.2	0.2
Jun-03	0.3	0.3	2.1	0.3	0.3
Jun-16	0.3	0.3	2.0	0.3	0.3
Jul-01	0.3	0.3	2.3	0.3	0.3
Jul-22	0.2	0.2	1.6	0.2	0.2
Aug-06	0.3	0.3	1.6	0.3	0.3
Aug-20	0.2	0.2	1.3	0.2	0.2
Sep-02	0.4	0.4	1.8	0.4	0.4
Sep-16	0.2	0.2	1.9	0.5	0.4
Oct-08	0.2	0.2	1.1	0.3	0.2
Oct-20	0.5	0.5	1.2	0.5	0.5
Nov-04	0.2	0.2	1.0	0.3	0.2
Nov-18	0.2	0.2	0.8	0.2	0.2
Dec-02	0.1	0.1	1.3	0.2	0.2
Dec-16	0.1	0.1	0.8	0.1	0.1

Table 16

Soluble Orthophosphate (mg/L-P) Values for the Cedar River near the Duane Arnold Energy Center during 1998

Date 1998	Sampling Locations: Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-07	0.2	0.2	0.9	0.2	0.2
Jan-22	0.2	0.2	0.8	0.2	0.2
Feb-04	0.2	0.2	0.9	0.2	0.2
Feb-18	0.3	0.3	0.4	0.3	0.3
Mar-04	0.2	0.2	0.9	0.1	0.2
Mar-19	0.2	0.2	0.5	0.2	0.2
Apr-01	0.2	0.2	0.2	0.2	0.2
Apr-15	0.1	0.1	0.1	0.1	0.1
May-04	<0.1	<0.1	<0.1	<0.1	<0.1
May-20	0.1	0.1	0.1	0.1	0.1
Jun-03	<0.1	<0.1	0.7	<0.1	<0.1
Jun-16	0.1	0.1	0.7	0.1	0.1
Jul-01	0.2	0.2	0.4	0.2	0.2
Jul-22	<0.1	<0.1	0.7	<0.1	<0.1
Aug-06	<0.1	<0.1	0.8	<0.1	<0.1
Aug-20	<0.1	<0.1	0.8	<0.1	<0.1
Sep-02	0.2	0.2	1.0	0.2	0.2
Sep-16	<0.1	<0.1	1.0	<0.1	<0.1
Oct-08	0.1	0.1	0.8	0.1	0.1
Oct-20	0.2	0.2	0.8	0.2	0.2
Nov-04	0.1	0.1	0.5	0.1	0.1
Nov-18	0.1	0.1	0.5	0.1	0.1
Dec-02	0.1	0.1	0.6	0.1	0.1
Dec-16	0.1	0.1	0.2	0.1	0.1

Table 17

Ammonia (mg/L-N) Values for the Cedar River near the Duane Arnold Energy Center during 1998

Date 1998	Sampling Locations: Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-07	<0.1	<0.1	0.2	<0.1	<0.1
Jan-22	0.1	0.1	0.1	0.1	0.1
Feb-04	0.2	0.2	<0.1	0.2	0.2
Feb-18	0.3	0.2	0.2	0.3	0.2
Mar-04	0.1	0.1	0.1	0.1	0.1
Mar-19	0.1	<0.1	0.1	<0.1	<0.1
Apr-01	<0.1	<0.1	0.3	0.1	<0.1
Apr-15	<0.1	<0.1	<0.1	<0.1	<0.1
May-04	<0.1	<0.1	<0.1	<0.1	<0.1
May-20	<0.1	<0.1	<0.1	<0.1	<0.1
Jun-03	<0.1	<0.1	<0.1	<0.1	<0.1
Jun-16	<0.1	0.1	0.5	0.1	0.1
Jul-01	<0.1	<0.1	<0.1	<0.1	<0.1
Jul-22	<0.1	<0.1	0.2	<0.1	<0.1
Aug-06	<0.1	<0.1	0.5	<0.1	<0.1
Aug-20	<0.1	<0.1	0.7	<0.1	<0.1
Sep-02	<0.1	<0.1	0.2	<0.1	<0.1
Sep-16	0.1	<0.1	0.6	0.1	0.1
Oct-08	<0.1	<0.1	1.4	<0.1	<0.1
Oct-20	<0.1	<0.1	1.2	<0.1	<0.1
Nov-04	<0.1	<0.1	0.4	<0.1	<0.1
Nov-18	<0.1	<0.1	0.2	<0.1	<0.1
Dec-02	<0.1	<0.1	0.2	<0.1	<0.1
Dec-16	<0.1	<0.1	0.2	<0.1	<0.1

Table 18

Nitrate (mg/L)-N Values for the Cedar River
near the Duane Arnold Energy Center during 1998

Date 1998	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 Feet Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
	Sampling Locations				
Jan-07	7.6	7.2	18	7.6	7.6
Jan-22	6.2	6.7	17	7.0	6.9
Feb-04	5.3	5.3	16	5.6	5.7
Feb-18	5.8	6.0	7.4	6.1	6.0
Mar-04	9.7	9.8	25	10	9.9
Mar-19	8.9	8.6	18	8.8	8.9
Apr-01	8.9	8.1	4.2	8.1	8.4
Apr-15	11	11	9.8	11	11
May-04	9.0	9.2	7.6	9.3	9.1
May-20	7.1	7.0	7.2	7.1	7.1
Jun-03	12	12	41	13	12
Jun-16	12	11	32	12	11
Jul-01	7.7	7.8	17	7.9	7.7
Jul-22	5.7	5.5	22	5.3	5.6
Aug-06	3.3	3.3	8.3	3.4	3.4
Aug-20	3.4	3.3	11	3.5	3.4
Sep-02	4.0	4.0	13	4.3	4.0
Sep-16	3.2	3.1	9.8	3.4	3.2
Oct-08	6.3	6.2	9.6	6.4	6.4
Oct-20	6.3	6.3	10	6.4	6.4
Nov-04	9.3	9.5	17	9.5	9.1
Nov-18	9.5	9.4	16	9.7	9.5
Dec-02	8.0	7.9	13	8.1	8.2
Dec-16	7.9	7.7	5.2	7.6	7.6

Table 19

Total Iron (mg/L) Values for the Cedar River near the Duane Arnold Energy Center during 1998

Date 1998	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	Sampling Locations				
	1	2	5	3	4
Jan-07	0.59	0.63	0.69	0.82	0.40
Jan-22	0.12	0.06	0.35	0.07	0.07
Feb-04	0.29	0.24	0.72	0.27	0.27
Feb-18	4.4	3.8	0.89	3.0	3.8
Mar-04	1.3	0.99	1.1	1.1	1.2
Mar-19	1.8	1.8	0.79	1.9	1.9
Apr-01	7.1	6.0	0.96	6.6	5.7
Apr-15	3.3	3.1	2.5	3.0	3.1
May-04	1.9	2.0	1.4	1.9	2.0
May-20	1.7	1.8	1.6	1.7	1.7
Jun-03	3.7	3.2	10	3.8	3.6
Jun-16	4.8	4.0	12	4.2	4.4
Jul-01	2.8	2.3	5.9	2.5	2.4
Jul-22	2.1	1.8	2.1	2.2	2.2
Aug-06	3.1	2.7	1.6	2.5	2.3
Aug-20	1.1	1.0	0.65	0.92	1.2
Sep-02	2.6	2.4	2.8	2.5	2.2
Sep-16	0.73	0.69	0.89	1.7	1.5
Oct-08	1.9	1.8	0.99	1.9	1.6
Oct-20	8.4	7.8	2.0	7.7	7.7
Nov-04	1.2	1.3	2.4	1.4	1.3
Nov-18	1.0	1.0	0.96	0.66	0.85
Dec-02	0.94	0.85	1.0	0.86	0.88
Dec-16	0.41	0.36	1.7	0.42	0.36

Table 20

Biochemical Oxygen Demand (5 day in mg/L) Values for the Cedar River near the Duane Arnold Energy Center during 1998

	Sampling Locations				
Date 1998	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-07	2	2	2	2	2
Jan-22	<1	<1	<1	<1	<1
Feb-04	2	2	1	2	2
Feb-18	6	4	1	5	5
Mar-04	2	2	2	3	3
Mar-19	2	2	1	2	2
Apr-01	3	3	2	3	2
Apr-15	2	2	2	2	2
May-04	3	3	2	3	3
May-20	7	7	7	7	7
Jun-03	3	3	5	3	3
Jun-16	1	1	6	1	1
Jul-01	1	1	3	1	<1
Jul-22	6	7	9	7	6
Aug-06	4	6	7	6	6
Aug-20	3	8	7	8	7
Sep-02	3	3	7	3	3
Sep-16	6	6	5	7	7
Oct-08	2	2	2	2	2
Oct-20	3	4	2	4	4
Nov-04	<1	1	<1	1	<1
Nov-18	2	2	2	1	1
Dec-02	2	2	2	2	2
Dec-16	<1	1	1	1	2

Table 21

Coliform Bacteria (Fecal Organisms/100 ml) Values for the Cedar River near the Duane Arnold Energy Center during 1998

Date 1998	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-07	560	520	870	580	450
Jan-22	50	20	45	18	30
Feb-04	82	40	30	45	80
Feb-18	200	100	20	200	100
Mar-04	210	180	30	210	190
Mar-19	600	520	130	430	450
Apr-01	4000	3700	61,000	3200	2800
Apr-15	500	240	250	280	290
May-04	120	90	90	150	50
May-20	30	20	20	100	<10
Jun-03	150	140	910	190	160
Jun-16	1700	1500	1300	2400	1900
Jul-01	420	380	50	300	500
Jul-22	73	30	350	90	130
Aug-06	4800	4200	3200	5100	2900
Aug-20	260	180	200	290	210
Sep-02	200	160	400	220	110
Sep-16	110	130	1300	140	140
Oct-08	2000	1300	980	1200	940
Oct-20	3800	3500	1100	3000	3700
Nov-04	200	330	950	290	270
Nov-18	210	220	370	150	270
Dec-02	180	64	<10	160	150
Dec-16	60	30	80	40	30

Table 22

Coliform Bacteria (E. coli/100 ml) Values for the Cedar River near the Duane Arnold Energy Center during 1998

	Sampling Locations				
Date 1998	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-07	490	640	800	680	600
Jan-22	30	20	55	30	36
Feb-04	55	36	30	30	64
Feb-18	230	150	20	180	154
Mar-04	150	91	55	100	130
Mar-19	770	680	320	720	580
Apr-01	2900	2800	77,000	3600	3600
Apr-15	400	230	290	310	270
May-04	220	140	36	230	170
May-20	10	30	170	10	40
Jun-03	120	180	820	170	170
Jun-16	870	1200	1000	310	2900
Jul-01	310	480	80	310	330
Jul-22	50	91	6000	200	210
Aug-06	3400	3800	1600	4000	2000
Aug-20	270	270	230	200	250
Sep-02	200	170	910	180	230
Sep-16	150	150	270	140	160
Oct-08	1400	1200	940	2000	1000
Oct-20	3400	3400	1300	3800	2700
Nov-04	200	240	860	250	180
Nov-18	150	130	500	110	250
Dec-02	200	110	18	100	120
Dec-16	73	18	40	20	27

Table 23

Additional Chemical Analysis-1998

Station	Cl (mg/L)	SO_4 (mg/L)	Metals (ug/L) Cr	Cu	Pb	Mn	Hg	Zn
				Apr-15				
1. Lewis Access	21	26	<20	<10	<10	140	<1	30
2. Upstream DAEC	20	26	<20	<10	<10	130	<1	220
3. Downstream DAEC	22	26	<20	<10	<10	150	<1	<20
4. One-half mile below plant	20	26	<20	<10	<10	140	<1	<20
5. Discharge Canal	23	29	<20	<10	<10	110	<1	<20
				Jul-01				
1. Lewis Access	15	17	<20	<10	<10	100	<1	30
2. Upstream DAEC	14	18	<20	<10	<10	50	<1	40
3. Downstream DAEC	10	20	<20	<10	<10	100	<1	170
4. One-half mile below plant	10	19	<20	<10	<10	90	<1	40
5. Discharge Canal	34	160	50	20	<10	650	<1	1500

Table 24

Benthic macroinvertebrates collected on Hester-Dendy artificial substrates from the Cedar River and the discharge canal in the vicinity of the Duane Arnold Engery Center
7/20/98 - 8/26/98

Taxon	Collection Site Lewis Access	U/S DAEC	D/S DAEC	1/2 mile D/S	Discharge Canal
Nematoda		3	2		
Annelida					
Oligochaeta					
Naiadidae			1	2	
Arthropoda					
Insecta					
Coleoptera (Beetles)					
Elmidae					
Macronychus sp.		1			
Stenelmis spp.		2			
Diptera					
Chironomidae	8320	3550	3820	3490	1
Simuliidae					
Simulium spp.	93	70	7	4	
Empididae					
Hemerodromia spp	15	15	2	15	
Ephemeroptera (Mayflies)					
Baetidae	14	7	2		
Baetis intercalaris	5	13	4	1	
Fallceon quilleri	1	1			
Labiobaetis longipalpus	39	13	16	39	
Caenidae					
Amercaenis ridens	2	1	3		
Caenis hilaris	1	7	57	11	
Heptageniidae					
Heptagenia flavescens	8	19	1	15	
Stenonema exiguum			1		
Stenonema mexicanum	2	10	18	32	
Stenonema pulchellum		1			
Stenonema terminatum	3	17	18	12	
Stenonema spp.				3	
Isonychiidae					
Isonychia sicca	1	4	7	1	
Isonychia spp.	3	8	19	5	
Tricorythidae					
Tricorythodes spp.	2		29	7	
Plecoptera (Stoneflies)					
Perlidae					
Acroneuria spp.	3	2	2		
Pteronarcyidae					
Pteronarcys spp.	1				
Trichoptera (Caddisflies)					
Brachycentridae					
Brachycentrus numerosus		1			
Hydropsychidae					
Ceratopsyche bronta	1				
Ceratopsyche morosa (bifida)	4			1	
Cheumatopsyche spp.	15	4	11	6	
Hydropsyche bidens	875	197	114	552	1
Hydropsyche orris	279	20	33	98	
Hydropsyche simulans	85	8	10	52	
Potamyia flava	373	64	120	77	
Polycentropodidae					
Neureclipsis sp.	1				

Table 24 (con't)

Benthic macroinvertebrates collected on Hester-Dendy artificial substrates from the Cedar River and the discharge canal in the vicinity of the Duane Arnold Engery Center
7/20/98 - 8/26/98

	Collection Site				
Taxon	Lewis Access	U/S DAEC	D/S DAEC	1/2 mile D/S	Discharge Canal
Total Organisms	**10,145**	**4,038**	**4,297**	**4,423**	**2**
No. Organisms/m^2	**101,450**	**40,380**	**42,970**	**44,230**	**20**

*DAEC Discharge Canal

Samples were collected using Hester-Dendy artifical substrate samplers. Samplers were composed of five plates measuring approximately 0.01 m^2 per side per plate.

Table 24 (con't)

Benthic macroinvertebrates collected on Hester-Dendy artificial substrates from
the Cedar River and the discharge canal in the vicinity of the Duane Arnold Engery Center
8/28/98 - 10/8/98

Taxon	Collection Site Lewis Access	 U/S DAEC	 D/S DAEC	 1/2 mile D/S	 Discharge Canal
Platyhelminthes					
Turbellaria					
Planariidae					
Dugesia sp.			6	14	11
Annelida					
Oligochaeta					
Naiadidae		212	16	14	
Tubificidae			8		54
Hirudinea					
Pharyngodellida					
Erpobdellidae					
Helobdella stagnalis					1
Mollusca					
Gastropoda					
Physidae					
Physa sp.					640
Arthropoda					
Insecta					
Coleoptera (Beetles)					
Elmidae					
Stenelmis sp.		4			
Macronychus sp.				2	
Diptera					
Chironomidae		792	650	894	57
Simuliidae					
Simulium spp.		4	16		
Empididae					
Hemerodromia spp.		114	12	40	
Ephemeroptera (Mayflies)					
Baetidae					
Baetis intercalaris		4	2		
Labiobaetis longipalpus		8	2		
Caenidae					
Caenis hilaris				4	
Heptageniidae				6	
Heptagenia flavescens		24	4	84	
Stenonema mexicanum		4		8	
Stenonema terminatum		112	148	110	
Isonychiidae					
Isonychia spp.		4	2	4	
Tricorythidae					
Tricorythodes spp.		2		6	
Odonata (Zygoptera)					
Coenagrionidae					
Argia spp.				2	1
Plecoptera					
Perlidae					
Acroneuria sp.			2	2	
Perlodidae					
Isoperla spp. (small)		6			
Taeniopterygidae					
Taeniopteryx spp.			2	2	

Table 24 (con't)

Benthic macroinvertebrates collected on Hester-Dendy artificial substrates from the Cedar River and the discharge canal in the vicinity of the Duane Arnold Engery Center
8/28/98 - 10/8/98

Taxon	Collection Site: Lewis Access	U/S DAEC	D/S DAEC	1/2 mile D/S	Discharge Canal
Trichoptera (Caddisflies)					
Cheumatopsyche spp.		16	6	16	
Hydropsyche bidens		1256	168	932	2
Hydropsyche orris		64	38	108	
Hydropsyche simulans		22	18	18	
Potamyia flava		274	174	342	1
Leptoceridae					
Nectopsyche spp.		2	4	2	
Polycentropodidae					
Neureclipsis sp.			2	2	
Total Organisms	-	**2,924**	**1,280**	**2,612**	**767**
No. Organisms/m^2	-	**29,240**	**12,800**	**26,120**	**7,670**

*DAEC Discharge Canal
**No substrates were recovered from this site

Samples were collected using Hester-Dendy artifical substrate samplers. Samplers were composed of five plates measuring approximately 0.01 m^2 per side per plate.

Table 25

Daily Numbers of Fish Impinged at the Duane Arnold Energy Center
January - December 1998

Day of the Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	1	0	1	0	0	0	1	0	0	1	0	1
2	0	0	0	0	0	0	0	0	0	2	0	0
3	1	0	*	0	0	0	0	0	0	0	0	0
4	1	0	0	0	0	0	0	0	0	0	0	0
5	2	0	0	0	1	0	0	0	0	0	1	0
6	1	0	3	0	0	0	0	0	0	0	7	0
7	0	0	0	0	0	0	0	1	0	0	6	*
8	5	0	3	1	0	0	0	0	1	0	5	2
9	0	0	1	0	0	0	1	0	0	0	0	0
10	3	2	3	0	0	0	0	0	0	0	0	3
11	4	15	2	0	2	2	0	0	0	0	1	12
12	0	4	*	0	0	0	0	0	0	0	1	7
13	2	14	*	0	0	0	0	2	0	*	2	0
14	0	4	*	0	0	0	0	1	0	*	0	0
15	0	23	7	1	0	0	2	0	1	1	0	1
16	0	8	5	0	0	0	0	0	0	0	1	7
17	0	4	3	0	0	0	0	0	0	0	2	6
18	0	1	6	2	0	0	0	0	0	0	0	3
19	0	3	9	0	2	0	0	0	0	0	2	1
20	0	3	12	0	0	0	0	0	0	0	3	4
21	1	5	5	0	0	1	0	0	0	0	4	0
22	2	2	5	0	0	0	0	0	1	0	2	6
23	0	2	5	0	0	0	0	0	0	0	4	3
24	0	1	7	0	0	0	0	0	0	0	2	21
25	0	2	1	1	0	1	0	0	0	0	2	4
26	3	7	1	0	0	1	0	0	0	0	2	*
27	0	4	2	0	0	0	1	0	0	0	1	3
28	1	0	0	0	0	0	0	0	0	0	1	4
29	1	-	2	0	0	0	1	0	0	0	0	0
30	0	-	2	0	0	0	1	0	0	0	1	3
31	0	-	2	-	0	-	0	0	-	0	-	1
Total	28	104	87	5	5	5	7	4	3	4	50	92

Total Annual 394

*No data

Table 26

Comparison of Average Values for Several Parameters at Upstream, Downstream and Discharge Canal Locations at the Duane Arnold Energy Center During Periods of Station Operation-1998

Parameters	Upstream (Station 2)	Discharge Canal (Station 5)	Downstream (Station 4)
Temperature (°C)	12.4	14.9	12.7 (103%)
Dissolved Solids (mg/L)	323	1270	335 (104%)
Total Hardness (mg/L)	292	899	310 (106%)
Total Phosphate (mg/L)	0.28	1.45	0.30 (107%)
Nitrate (mg/L as N)	7.1	15.9	7.2 (101%)
Iron (mg/L)	2.22	2.39	2.27 (102%)

*Percent of upstream level ()

Table 27

Comparison of Average Yearly Values for Several Parameters in the Cedar River Upstream of the Duane Arnold Energy Center*
1972-1998

Year	Mean flow** (cfs)	Turbidiity (NTU)	Total PO_4 (mg/L)	Ammonia (mg/L-N)	Nitrate (mg/L-N)	BOD (mg/L)	Total Hardness (mg/L)
1972	4,418	22	1.10	0.56	0.23	5.7	253
1973	7,900	28	0.84	0.36	1.5	4.0	250
1974	5,580	29	2.10	0.17	4.2	4.7	266
1975	4,206	58	1.08	0.33	2.8	6.5	251
1976	2,082	41	0.25	0.25	2.8	7.3	233
1977	1,393	15	0.33	0.52	2.9	6.5	243
1978	3,709	23	0.26	0.22	4.4	3.3	261
1979	7,041	26	0.29	0.12	6.6	2.5	272
1980	4,523	40	0.34	0.19	5.4	4.3	238
1981	3,610	33	0.77	0.24	6.0	6.5	279
1982	7,252	43	0.56	0.23	8.0	5.1	274
1983	8,912	22	0.25	0.10	8.6	3.3	259
1984	7,325	40	0.32	0.10	5.9	3.9	264
1985	3,250	30	0.31	0.11	4.8	6.7	245
1986	6,475	33	0.26	0.10	6.8	3.7	285
1987	2,625	32	0.24	0.06	5.6	5.8	269
1988	1,546	28	0.30	<0.16	2.8	9.6	246
1989	947	24	0.37	<0.30	1.5	10.3	224
1990	5,061	33	0.29	<0.20	7.3	4.8	283
1991	8,085	65	0.38	<0.20	7.9	4.3	268
1992	5,717	49	0.31	<0.16	6.4	5.5	261
1993	15,900	44	0.27	<0.16	6.2	2.3	276
1994	4,701	34	0.28	<0.22	5.1	5.3	269
1995	4,384	31	0.21	<0.17	5.5	4.0	275
1996	3,200	34	0.29	<0.21	4.7	7.0	254
1997	4,996	38	0.3	<0.24	5.1	5.7	248
1998	6,024	41	0.26	<0.10	7.4	2.8	287

*Data from Lewis Access location (Station 1)

**Data from U.S. Geological Survey Cedar Rapids gauging station

Table 28

Summary of Relative Loading Values (Average Annual Concentration x Cumulative Runoff) for Several Parameters in the Cedar River Upstream of the Duane Arnold Energy Center
1972-1998

Year	Mean flow** (cfs)	Cumulative** Runoff (in)	Turbidity (mg/L)	Total PO4 (mg/L0	Ammonia (mg/L-N)	Nitrate (mg/L-N)	BOD (mg/L)
1972	4,418	9.24	203	10.2	5.2	2	53
1973	7,900	16.48	461	13.8	5.9	25	66
1974	5,580	11.64	338	24.4	5.0	49	55
1975	4,206	8.77	509	9.5	2.9	25	57
1976	2,082	4.35	178	1.1	1.1	12	32
1977	1,393	2.91	44	1.0	1.5	8	19
1978	3,709	7.74	178	2.0	1.7	34	26
1979	7,041	14.79	385	4.3	1.8	98	37
1980	4,523	9.45	378	3.2	1.8	51	41
1981	3,610	7.53	248	5.8	1.8	45	49
1982	7,252	15.13	651	8.5	3.5	121	77
1983	8,912	18.00	396	4.5	1.8	155	59
1984	7,325	15.22	609	4.9	1.5	90	59
1985	3,250	6.80	204	2.1	0.8	33	46
1986	6,375	13.11	433	3.4	1.3	89	49
1987	2,625	4.85	155	1.2	0.3	27	28
1988	1,546	2.85	80	0.9	<0.4	8	27
1989	947	1.84	44	0.7	0.6	3	19
1990	5,061	9.34	308	2.7	1.9	68	45
1991	8,085	17.15	1115	6.5	3.4	135	74
1992	5,717	10.92	535	3.4	1.7	70	61
1993	15,900	32.39	1425	8.8	5.2	201	74
1994	4,701	10.45	355	2.9	2.3	53	55
1995	4,384	9.23	286	1.9	1.6	51	37
1996	3,200	6.67	227	1.9	1.4	31	47
1997	4,996	10.44	397	3.13	2.5	53	60
19982	6,024	12.48	512	3.24	<1.25	92	35

*Data from Lewis Access location (Station 1)

**Data from U.S. Geological Survey Cedar Rapids gauging station

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